MILESTONES -   STRICT MILESTONE SCHEDULES - CONSTRUCTION AND LAUNCH WITHIN
                [3] YEARS OF AUTHORIZATION
                FCC MONITORS CONSTRUCTION SCHEDULE
                LICENSE REPORTS 6 MONTH PERIODS
                ENTIRE SYSTEM LAUNCHED AND OPERATING WITHIN [6] YEARS OF
                AUTHORIZATION

APPROACH (CONT.)

STANDING COMMITTEE

o   FCC RECOGNITION AND OVERSIGHT

o   MEMBERS - ALL OPERATORS THAT HAVE LICENSE

o   FUNCTIONS

- FORUM TO COORDINATE USE OF SPECTRUM BY THESE U.S. SYSTEMS AROUND THE WORLD. REQUIREMENTS OF EACH U.S. SYSTEM VARY - COMMITTEE DETERMINES AMOUNT OF SPECTRUM TO BE USED BY EACH AROUND THE WORLD.

- DEVELOP PROPOSALS TO SOLVE INTERFERENCE ISSUES AROUND THE WORLD. FCC USES PROPOSALS FOR "COORDINATION" WITH OTHER ADMINISTRATIONS AND WITH U.S. GOVERNMENT.

APPROACH (CONT.)

ASSIGNMENTS:

- o   FCC MAKES ASSIGNMENTS AT LAUNCH
- o   1616-1626.5 MHZ
    - o   10.5/N MHZ ASSIGNED TO EACH OF N LICENSEES
    - o   FDMA SYSTEMS ASSIGNED SPECTRUM
        1626.5 MHZ AND DOWN
    - o   CDMA SYSTEMS ASSIGNED SPECTRUM
        1616 MHZ AND UP
    - o   IF TWO OR MORE CDMA SYSTEMS LAUNCH, EACH WOULD POOL
        INDIVIDUAL ASSIGNMENTS AND USE IN COMMON BY ALL CDMA
        OPERATORS

REASSIGNMENTS

O   IF LICENSEE DOES NOT LAUNCH FIRST SATELLITE WITHIN [3] YEARS OF INITIAL
CONSTRUCTION AND LAUNCH AUTHORIZATION

FCC REASSIGNS SPECTRUM EQUALLY AMONGST OTHER OPERATING SATELLITE SYSTEMS

O   IF A LICENSEE HAS NOT LAUNCHED ITS ENTIRE SYSTEM WITHIN [6] YEARS OF
GRANT OF CONSTRUCTION AUTHORIZATION

FCC MAY RECOVER EXCESS SPECTRUM AND REASSIGN IT AMONG OTHER FULLY
OPERATIONAL SYSTEMS

1610-1616 MHZ

o AVAILABLE AS A COMMON POOL FOR LICENSED CDMA SYSTEM, AGREEMENTS AND IN ACCORDANCE WITH COORDINATION

o RESOLUTION OF GLONASS ISSUE

o TOTAL SPECTRUM (16.5 MHZ SHARED AMONGST CDMA OPERATORS FDMA/CDMA PARTITION MOVES TO REFLECT AND EQUAL REDISTRIBUTION AMONGST OPERATIONAL SYSTEMS

TECHNICAL

- CDMA SPECTRUM POOLS - OPERATORS HAVE EQUITABLE SHARING OF INTERFERENCE POWER IN UPLINK AND DOWNLINK DIRECTION

- STANDING COMMITTEE USED TO DETERMINE APPROPRIATE VALUES CONSISTENT WITH

  - ITU RADIO REGULATIONS
  - COORDINATION AGREEMENTS

- DEFAULT VALUES USED IN CASES OR DISAGREEMENT

FUTURE EXPANSION

o U.S. GOVERNMENT WOULD SEEK ADDITIONAL MSS ALLOCATIONS AT FUTURE WARC'S.

o ELIGIBILITY CRITERIA FOR ENTRY DETERMINED WHEN SPECTRUM ALLOCATED DOMESTICALLY OR WHEN SERVICE RULES DEVELOPED

APPROACH (CONT.)

ASSIGNMENTS:

- FCC MAKES ASSIGNMENTS AT LAUNCH
- 1616-1626.5 MHZ
    - ASSIGNED EQUALLY BETWEEN CDMA AND FDMA TECHNOLOGIES
    - 5.25 MHZ AVAILABLE TO EACH TECHNOLOGY IN THE USA
    - SUBJECT TO INTERNATIONAL COORDINATION

- FDMA ASSIGNED 1621.25-1626.5 MHZ
    - FIRST FDMA SYSTEM LAUNCHED - ENTIRE 5.25 MHZ
    - SECOND FDMA SYSTEM LAUNCHED - SPLIT 5.25 MHZ

- CDMA ASSIGNED 1616-1621.25 MHZ
    - FIRST CDMA SYSTEMS USES ENTIRE BAND
    - SECOND SUBSEQUENT CDMA SYSTEMS POOL THE 5.25 MHZ

REASSIGNMENTS:

o   IF EITHER TECHNOLOGY DOES NOT DEVELOP WITHIN [3] YEARS AFTER
    AUTHORIZATION, EXCESS SPECTRUM REASSIGNED BY FCC TO SUCCESSFUL
    TECHNOLOGY

o   IF NO LICENSEE IMPLEMENTS A PARTICULAR TECHNOLOGY BY LAUNCHING AN
    ENTIRE SYSTEM WITHIN [6] YEARS OF GRANT - FCC RECOVERS AND
    REASSIGNS EXCESS SPECTRUM

1610-1616 MHZ

o AVAILABLE AS A COMMON POOL FOR LICENSED CDMA SYSTEMS

o IN ACCORDANCE WITH COORDINATION AGREEMENTS

o RESOLUTION OF GLONASS ISSUE

Addendum to Report of The Mobile Satellite Service (MSS) Above 1
GHz Negotiated Rulemaking Committee:

Sharing with Services other than ARNS and RAS (April 6, 1993)

Submitted by: **Loral Qualcomm Satellite Services, Inc.**

Supported by: TRW Inc., Ellipsat Corporation and Constellation
               Communications, Inc.

     The Drafting Group 2C Report of IWG-2 contains language in
Section 4.8 which suggests that MSS downlink transmissions in the
2483.5-2500 MHz band may not be feasible in urban areas and may
experience interference even in sparsely populated areas. LQSS
acknowledges that ISM interference exists, but does not agree with
the conclusion that it represents a significant problem to MSS and
that operation in only sparsely populated areas may be possible.

     First, it must be noted that the statements in Section 4.8
are based upon an NTIA study, which was concerned with use of the
2483.5-2500 MHz band for **MSS uplinks**, not MSS downlinks.
Therefore, the NTIA results and conclusions may not be directly
applicable to MSS downlink operations.

     Second, the measurements conducted by NTIA indicate that
there may be a cumulative environment ISM interference in urban
areas. However, due to the limited testing and the configuration
of the test, with respect to operation of MSS systems, the study
cannot be deemed conclusive. MSS user terminals operating in such
areas may experience varying levels of cumulative interference
which may under certain circumstances exceed the thermal noise of
the receiver.

     Moreover, there are several mitigating effects which may
reduce or eliminate the interference when operating in areas where
there are concentrations of ISM devices. These mitigating effects
are: shadowing and blocking, MES antenna patterns which reject ISM
signals arriving most of the time at 0 degree elevation angles,
and the ability of the CDMA link by link power control factor to
overcome interference.

Shadowing & Blocking

     The Globalstar MES user antenna pattern will provide
significant rejection to interfering signals that are received in
the horizontal direction. For those users operating in urban
areas, the additional path loss from horizontal sources, such as
microwave ovens, will be significant due to the walls of the
building in which the ISM interfering source is housed, plus
shadowing due to trees, blockage from buildings, etc. This
blockage was not accounted for in the NTIA study. Vogel's
analysis of building penetration path loss indicates that 16 dB is
a typical value at 2.4 GHz. Urban path loss at ranges of 300 m or

more can be expected to be on the order of 40 dB or more higher than free space loss depending upon distance from the radiating source.

MES Antenna Patterns

Significant rejection to interfering signals that are received in the horizontal direction can be achieved by the Globalstar MES user antenna pattern. For those users operating on hillsides overlooking urban areas, such as Boulder, CO, in the NTIA study, the MES antenna sidelobe rejection in the direction of potential interference is again significantly increased on the order of over 20 dB from the path of the desired Globalstar signal. Therefore, the expected interfering signal level at the MES receiver input is expected to be significantly reduced from the extrapolated interfering power flux density levels based upon the NTIA study.

CDMA Power Control

The Globalstar system incorporates CDMA which is an excellent spread spectrum technique for mitigating interfering signals. Should a Globalstar MES user operate in a high ISM interference area, the Globalstar system can increase the power in the satellite downlink S-Band signal to that particular user via the closed loop power control capability under the command of the Globalstar Gateway. Over 10 dB of forward path power control is available while still remaining within the constraints of the S-Band spectral power flux density limits. Since many users occupy the same RF channel, increasing the power to one user does not significantly increase the total power and PFD within the channel.

The Globalstar noise floor is equivalent to a PFD of about -140 dBW/m^2/4 kHz. This is approximately the average interference value in paragraph 4.8 of the Drafting Group C report based upon data at 2480 MHz from several microwave ovens in the NTIA report. In reviewing the NTIA data for these ovens, it appears that the average emission density over the 2483.5 to 2500 MHz band would be 20 dB lower or -162 dBW/m^2/4 kHz which is 22 dB below the Globalstar noise floor. The Globalstar system is well equipped to operate in this type of environment. As mentioned previously the Globalstar CDMA technique is well suited to counter not only interference from other MSS satellites, but also interference from the ISM band.

Interfering Power Flux Density Calculation

Based upon these mitigating factors, an MES user located in an urban area and 300 m from a signal microwave oven could expect an interfering power flux density (IPFD) of:

IPFD = PFD at 3 km + D - PL - UPLF

where PFD at 3 km equals -141 dBW/m^2/4 kHz

      D = free space loss reduction due to decreased distance
          or 20 dB
      PL = building penetration loss of 16 dB
      UPIF = urban path loss factor of at lest 40 dB.

     IPFD = -141 + 20 - 16 - 40 = -177 dBW/m^2/4 kHz

This is 37 dB below the Globalstar noise floor. Even with many microwave ovens operating, this should not present a problem in urban areas.

For the case of an MES user operating on a hillside near an urban area, the expected interfering flux density of nominally -103 dBW/m^2/4 kHz (as mentioned in paragraph 4.8.1) can be expected to be overcome by at least 20 dB of antenna rejection. The operator can improve this ratio by optimizing the orientation of the user handset. The Globalstar power control will also allow for at least 10 dB of additional downlink user power to overcome the interference. Nominally 12 dB of propagation loss due to foliage can be expected. Therefore, the composite interference is expected to be less than the Globalstar noise floor which is easily accommodated by the CDMA.

Conclusions on Sharing with the ISM

MES user terminals may operate in rural areas and thereby not be affected by cumulative ISM interference. For the occasional time that the MES terminal is located near a microwave oven when it is operating, the location of the user with respect to the ISM device is important. The input signal, in this case, to the MES will be mitigated by the MES antenna pattern and shadowing and blocking to about 20 db or more depending on the distance from the radiating source. In any case, should the interference be over the threshold both the power control and the path diversity combining gain will be used to mitigate the interference.

MES user terminals operating in suburban and urban areas and may experience some effect of cumulative interference. Since the shadowing and blocking of near zero elevation angle into the MES antenna is severe, and since the antenna pattern will reject horizontal interference, it is not expected to produce meaningful interference. MES user terminals operating on mountain areas overlooking urban areas, such as Boulder, Colorado, the MES antenna rejection of potential interference is also significantly increased over the desired Globalstar signal.

To the extent that there may be any interference from ISM there is also potential for dual mode operation using terrestrial cellular systems.

The potential interference from ISM devices, as more of these devices are deployed may increase. Further studies on levels of emissions under various conditions should be conducted in order to determine if additional measures of protection for the MSS systems are required.

An Alternate Analysis Based on NTIA Study

A somewhat different analysis, also based on the NTIA study, can lead to the conclusion that ISM will not be a problem in the MSS. We start with an average out-of-band emission figure of -60 dBm (4 ovens in Fig 3.1 of study averaged at 2480 MHz), measured at a distance of 3.0 m, in a 300 kHz bandwidth, and with a test antenna gain of 2.5 dBi. The flux density given by such a measurement is translatable into our terms, namely dBW/m^2-4 kHz by the equation

$$\phi = C - G_r + G_{1m2} - 10 \, \text{Log} \, (300/4)$$

$$\phi = -60 - 30 - 2.5 + 29.25 - 18.75$$

$$\phi = -82 \, dBW/m^2\text{-4 kHz}$$

At a distance of 300 m this translates, assuming free space propagation, into -122 dBW/m^2 -4kHz and at 3 km into a value of -142 dBW/m^2 -4 kHz.

In the reception of signals by an MES there are many factors that will serve to reduce this level of interference. A good MES antenna will be designed to have substantial rejection for horizontally propagated signals since it is designed to look upward at high elevation angles. This side lobe rejection can be the order of -20 dB in some cases and probably will average at least -10 dB. Building blockage (PL) can account for another 16 dB (according to Vogel) and urban path losses can be significantly in excess of the free space values (UPLF). This factor should be at least 40 dB. Under these circumstances the interference flux density is given by

$$\phi = \phi \, (\text{free space}) - PL - UPLF$$

$$\phi = -122 - 16 - 40$$

$$\phi = -178 \, dBW/m^2 \text{ -4 kHz}$$

This is well below the noise floor for any MES receiver operating at the prescribed flux density of -142 dBW/m^2 -4 kHz. Even allowing for interference from a number of ovens operating simultaneously there should be no trouble.

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STATEMENT OF ADDITIONAL VIEWS OF MOTOROLA

ON INTERFERENCE FROM ISM DEVICES

IN THE 2483.5-2500 MHz BAND

The 2400-2500 MHz band is allocated internationally by ITU footnote 752 and domestically by Part 18 of the Commission's Rules for use by Industrial, Scientific, and Medical (ISM) applications, including microwave ovens. There are 80 million microwave ovens in the United States, and 200 million microwave ovens worldwide. Since MSS applicants were not able to agree on the significance of the interference of ISM to MSS operations in the 2483.5-2500 MHz band, the Committee was not able to reach a consensus. Therefore, Motorola provides this Statement of its additional views.

NTIA Technical Memorandum 92-154 measured microwave oven emissions in the 2400-2500 MHz band. These measurements showed emissions at 2480 MHz averaging about -50 dBm in a 300 kHz bandwidth at the output of a 2.5 dB receiving antenna located 3 m from the oven. A technical analysis applying the NTIA data to proposed MSS operations in the 2483.5-2500 MHz band was presented to IWG2 (IWG2-70 (Rev 1)), and is attached as Exhibit 1 to this Statement. Motorola supports the conclusions in this analysis.

This analysis took the NTIA calculation of the mean EIRP, added 5 dB of margin, and concluded that the average interference power from ISM was still 36.5 dB above the thermal noise floor of a typical MSS receiver.

The ITU radio regulations establish a PFD coordination trigger of -142 dBW/sq m/4kHz. The MSS systems proposing to use this band would operate at or near this limit in order to maximize their capacity and avoid interference to other users in the band. If the power per channel is increased in the MSS downlink to overcome the interfering power, the number of channels served must be decreased. This would reduce the overall system capacity. Since the interference power is likely to be very high compared to the thermal noise, MSS satellites would probably not be able to transmit sufficient power to overcome the interference noise and provide a usable signal-to-noise ratio to the MSS receivers. As a result, MSS capacity in populated areas will be substantially reduced.

Accordingly, MSS downlink transmissions in the 2483.5-2500 MHz band may be limited to sparsely populated areas. Even downlinks in these sparsely populated areas may experience interference varying by location and time.

INTERFERENCE POWER DUE TO ISM EMITTERS IN THE 2483.5-2500 MHZ BAND

1. Introduction

The frequency band 2483.5-2500 MHz was allocated at WARC-92 to the Mobile Satellite Service (MSS) for space-to-Earth transmissions. The 2400-2500 MHz band is also allocated by footnote 752 in the ITU Radio Regulations for use by Industrial, Scientific and Medical (ISM) devices. The United States has restricted ISM use to the 2400-2483.5 MHz band. This paper identifies the sources of interference noise in the 2483.5-2500 MHz band from ISM uses, and determines the suitability of this band for MSS space-to-Earth communications.

ISM uses are many and varied with their use increasing. They include microwave ovens, high efficiency lighting systems, and industrial equipment. Wireless communications operating under Part 15 of the FCC's Rules also have been included in this analysis.

ISM devices use radio frequency (RF) energy for purposes other than communications. While consumer microwave ovens are not the only ISM devices in this band, they are by far the most prevalent.

In the United States, ISM emissions outside the ISM band are required to be suppressed below 25 microvolts/meter at 300 meters. Inside the ISM band, ISM emissions are unrestricted.

A report published by the NTIA[1] describes measurements made in the 2400-2500 MHz band by the Institute of Telecommunication Sciences (ITS) of Boulder, Colorado. The ITS Spectrum Use Measurement Group performed a very careful analysis and measurement program which quantified the interference emissions in this band. This paper uses the results of NTIA's analysis and test program to estimate the interference noise in this band relative to the thermal noise.

2. NTIA/ITS Tests

2.1 Description of the Test Scenarios

The following is a short summary of the testing that was conducted by NTIA/ITS. For a complete description of these tests, it is necessary to refer to the NTIA document.

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[1] NTIA Technical Memorandum 92-154, "Accommodation of Broadcast Satellite (Sound) and Mobile Satellite Services in the 2300-2450 MHz band", January 1992.

The purpose of the testing was to determine the feasibility of accommodating the Broadcast Satellite Service (BSS) between 2300 and 2410 MHz and the Mobile Satellite Service (MSS) in the Earth-to-space direction between 2390 and 2450 MHz. In conducting these tests, however, measurements were made in the 2483.5-2500 MHz band.

Two types of tests were conducted:

1) Measurements of the composite emissions at Boulder, Colorado from mountain sites overlooking the city, and

2) Characterization of the emissions of microwave ovens.

2.2   Measurements of Composite Emissions at Boulder, Colorado

The measurement of the composite emissions at Boulder are of most interest since they quantify the emissions from all interfering sources in the frequency band of interest. The population of Boulder is approximately 90,000 people.

The following is a summary of the data and analysis from the composite emission tests.

2.2.1   Description of the Measurements

The measurements were taken from two hilltops outside of Boulder - Green Mesa and Flagstaff. The purpose of those measurements was to estimate the equivalent EIRP of the ISM environment in the city.

Measurements of the aggregate emission spectrum were taken in a bandwidth of 30 kHz and measured over the entire band from 2300-2600 MHz. The source of the emission power was assumed to be emitters distributed across the field of veiw of the antenna.

2.2.1.1   Green Mesa Measurements

The measurements were taken from Green Mesa which is a hill approximately 155 meters high, 3.5 km from the geographic center of the city and 2.3 km from the closest concentration of significant radio emissions.

Figure 4-1 from the NTIA report shows the aggregate emission spectrum from Green Mesa. The data shows the maximum peak, mean peak and miminum peak data taken during a 24 hour period. The data is listed as received signal level. In the next section of this paper, this data is converted to the EIRP of the emitters using the receiver antenna gain and the distance to the center of the emissions.

2.2.1.2   Flagstaff Measurements

The measurements were taken from Flagstaff which is a hill approximately 610 meters high, 3.9 km from the geographic center of the city and 3.5 km from the closest concentration of significant radio emissions.

Figure 4-2 from the NTIA report shows the aggregate emission spectrum from Flagstaff. The received signal level is slightly lower than that of the Green Mesa tests but the measurements were made at a greater distance than the Green Mesa tests..

2.3   Analysis of the Measurements

2.3.1   Determination of the Equavalent EIRP

2.3.1.1   Green Mesa Tests

To determine the potential degradation of the ISM environment, the aggregate EIRP from the distributed emitters was calculated. This was done by collecting the total energy from the distributed emitters and determining the power of a single emitter that would equal the power of the distributed emitters.

The received peak EIRP is expressed as:

$$EIRP = P_r - G_r + L_p$$

where: EIRP = effective isotropic radiated power of the microwave ovens
                 or other sources in the Boulder area, in dBm

   P_r = received power at the measurement receiver input, in dBm

   G_r = gain of measurement receiving antenna, in dBi (2 dBi for cavity-backed spiral)

   L_p = free-space propagation path loss, in dB

The Green Mesa measurements showed a maximum peak power of -75 dBm at 2450 MHz. The maximum peak power in the 2483.5- 2500 MHz band was shown to be about -80 dBm. Computing the EIRP from the closest concentration of significant sources (2.3 km) results in the following:

$$EIRP = -75 - 2 + 107$$

$$EIRP = + 30 \text{ dBm @ 2450 MHz} (+25 \text{ dBm @ 2483.5-2500MHz})$$

Based upon these measurements at 2450 MHz, the NTIA report determined that a maximum peak EIRP of 1 Watt characterizes an ISM environment of approximately 90,000 people.

The report comments that since the aggregate emissions appear noise-like, a mean squared signal level would probably be 12 dB below the maximum peaks.

Extrapolating these results to the frequency band 2483.5-2500 MHz and adding an extra 5 dB of margin, the data indicates the following mean EIRP:

$$EIRP(\text{mean @ 2483.5-2500 MHz}) = 30 - 5 - 12 = 13 \text{ dBm}$$
$$= -17 \text{ dBW (mean)}$$

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2.3.1.2   Flagstaff Tests

The Flagstaff measurements showed a maximum peak power of -80 dBm at 2450 MHz. The maximum peak power was shown to be about -85 dBm at 2483.5-2500 MHz. The computed EIRP from the closest concentration of significant sources resulted in the following:

$$EIRP = -80 - 2 + 111$$

$$EIRP = + 29 \text{ dBm @ } 2450 \quad (+24 \text{ dBm @ } 2483.5\text{-}2500 \text{ MHz})$$

Once again, these figures approximated a maximum peak EIRP of 1 Watt.

Extrapolating these results to the frequency band 2483.5-2500 MHz and adding an extra 5 dB of margin, the data indicates the following mean EIRP:

$$EIRP = 29 - 5 - 12 = 12 \text{ dBm} = -18 \text{ dBW (mean)}$$

3.   Calculation of an Equivalent Interference Signal Power

The data from the NTIA report was then applied to the expected environment for MSS receivers operating in the 2483.5-2500 MHz frequency band.

This section extrapolates the NTIA data to estimate an average PFD from ISM sources in relation to the thermal noise level.

The average Interference Power Flux Density (IPFD) can be calculated as follows:

$$IPFD = EIRP \text{ (mean)} - A - R$$

where:

$IPFD$ = Estimated average power flux density of the interfering signal

$EIRP$ (mean) = Mean EIRP from the Green Mesa measurements (dBW)

A = The antenna on the hill above Boulder is assumed to see an area of approximately 7 km by 7 km or 49 square kilometers ($A = 76.9$ dB)

R = Ratio of 30 kHz to 4 kHz = 8.8 dB

$$IPFD = -17 - 76.9 - 8.8 = -102.7 \text{ dBW/sq m/4 kHz}$$

The equivalent average interfering power spectral density may be calculated as follows:

I_o = Average interfering power spectral density

$$I_o = IPFD - G - S$$

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where:

G = Gain of a 1 square meter antenna @ 2.5 GHz = 29.4 dB

S = 10 Log (4 kHz) = 36.0 dB

I_0 = -102.7 - 29.4 - 36 = - 168.1 dBW/Hz

This interfering power spectral density can be compared to the equivalent thermal noise as follows:

Assuming a typical MSS receiver has a noise temperature of 250 degrees Kelvin, the noise floor of the receiver is:

$N_0 = K + T$

where:

K = Boltzmann's constant = -228.6 dBW/Hz

T = System noise temperature = 250^0 K = 24 dB

N_0 = -228.6 + 24 = - 204.6 dBW/Hz

The average interference power compared to noise is:

$I_0 - N_0$ = - 168.1 + 204.6 = 36.5 dB

Since the interference should be at least 10 dB below the thermal noise, the interference problem is:

Problem = -168.1 + 214.6 = 46.5 dB

Accordingly, even though the EIRP level was reduced 17 dB below the ISM equivalent power calculated in the NTIA report, the average interference level is still significantly above the thermal noise floor of a typical MSS receiver.

4.   Confirmation of the Equavalent EIRP

In order to confirm the reasonableness of the EIRP values calculated above, a similar computation was made in the NTIA report. This was done by extrapolating the EIRP from a single oven to the number of ovens expected within the city of Boulder

$$EIRP = P_r - G_r - A_b + L_p + 10 \log N$$

where: EIRP = effective isotropic radiated power of the microwave
                        ovens or other sources in Boulder, in dBm

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P_r = received power frim a single oven at the measurement receiver input: -13 to -30 dBm

G = gain of measurement receiving antenna, in dBi (2 dBi)

A_b = building attenuation, in dB (typically 5 dB at 2450 MHz)

L_p = free-space propagation path loss for 3 meters, in dB

N = the number of ovens in Boulder operating at 2450 MHz at a specific instant (pop 90,000/2.5 pop per household x 80% x .001 activity factor).

EIRP = (-30 to -13 dBm) - 2 - 5 + 50 + 14

EIRP = + 27 to + 44 dBm @ 2450 MHz

Accordingly, the equivalent EIRP values determined by observing emissions over Boulder are consistent with those values extrapolated from individual ovens.

5.   Sources of Interfering Noise in the Band

There are many potential sources of interfering noise. They include microwave ovens, high efficiency lighting systems, industrial equipment, and wireless communications devices operating under Part 15.

In this section reference is made to a document, dated 3/11/93, which was provided by an AMSC representative to IWG 2 Drafting Group C . Attached to that document are the January-April 1991 filings made in General Docket #89-554 (Supplemental NOI on WARC 92) regarding the ISM use of the 2400-2500 MHz band. These filings detail many sources of potential ISM interference.

5.1   Microwave Ovens

Microwave ovens are by far the greatest use of the ISM band. There are an estimated 80 million ovens in use in the U.S. and approximately 200 million ovens world wide. For the last several years, an average of approximately 10 million ovens per year were manufactured and imported into the U.S.

The NTIA report indicates that the primary source of interference in this band is believed to be from microwave ovens. The NTIA document estimates that there are approximately 30,000 ovens in the Boulder area of which 300 are assumed to be in operation at any one time.

A potential anomoly exists between the spectral measurements made on the indivudual microwave ovens and the composite emission measurements made over the Boulder area. The microwave oven measurements show a sharp decrease of the radiated power in the 2483.5-2500 MHz band compared to the spectrum below 2483.5 MHz. The composite spectrum measurements, however, show only an approximate 5 dB decrease. This could be due to the operation of

other types of ISM devices or due to the actual performance of microwave ovens as they age and operate under various cooking conditions. Data presented in General Docket #89-554 indicates that such interference may indeed be due to microwave ovens.

5.2   Industrial Equipment

Use of the ISM band for industrial equipment is increasing. Many of these devices contain high power emitters. In its filing in General Docket #89-554, Fusion Systems of Rockille, Md. defined one type of industrial use of the ISM band. Fusion Systems states that it has manufactured thousands of microwave powered ultraviolet lamps for industrial use and that this equipment currently (April 1991) uses the entire 100 MHz band.

A typical leakage power within a building is 33 Watts (+ 15 dBW) in the ISM band. Assuming the power is equally distributed across the 100 MHz band and a 5 dB loss through the building walls, the EIRP outside of a building in the 2483.5-2500 MHz band is 1.9 Watts (+2.8 dBW). This level corresponds to an EIRP spectral density of - 78.2 dBW/Hz. It would require a free space distance of 12.3 miles to attenuate this signal to the thermal noise level of a 250 degree Kelvin MSS receiver.

The usage of this type of equipment is expected to increase.

5.3   High Efficiency Lighting Systems

Fusion Systems has also indicated that it has developed external lighting systems that utilize magnetrons. One application is using these lights for parking lots. A six lamp lighting system for a parking lot has been installed which has 12 magnetrons operating continuously during the night.. The continuous operation.of multiple magnetrons in an small area would provide a large interfering source in the 2483.5-2500 MHz band.

5.4   Wireless Communications

The ISM band may be used by many wireless communications in the near future. In the United States, these networks are operated under Part 15 of the FCC's Rules which define the modulation/multiple access techniques to be spread spectrum (either direct sequence or frequency hop). It is believed that systems under development for world wide use can also be used in the United States in accordance with Part 15.

The power limit for these devices is 1 Watt within the United States. It is not known if there are power limits on R-LAN usage in other parts of the world.

Although few of these devices are believed to be in use now, systems are under development and their usage is expected to increase dramatically within the next few years. In its filing in General Docket #89-554, Rose Communications estimates that over 1 million of these Part 15 devices could be operational within 3 to 4 years. Their out-of-band emissions will add to the general level of interference in the 2483.5-2500 MHz frequency band.

5.4.1   Radio Local Area Networks (R-LANs)

R-LAN's are wideband data links that operate in the band from 2400-2500 MHz (except for the United States where the band is restricted to 2400-2483.5 MHz). A potentially large usage of R-LAN's is for data exchange between portable (laptop) computers and their accessories (printers).

5.4.2   Medical Telemetry Applications

In its filing in General Docket #89-554, Radiant Systems indicates that it is developing Part 15 devices for medical telemetry applications in this band.

6.   Potential Methods for Mitigating ISM Interference

This section reviews the potential methods for mitigating ISM interference.

6.1   Suppression of the ISM Emissions

The AMSC document indicates that suppression of ISM emissions removed from 2450 MHz is not among the potential solutions to the problem.

6.2   Signal Processing

A potential solution is to process the interfering ISM signals out of the received MSS signal. The bursty nature of microwave oven emissions offers a potential for pulse blankers to mitigate the effects of interfering signals. This solution, however, has several drawbacks:

1)   No one signal processing solution is likely to eliminate interference from microwave ovens, high efficiency lighting systems, industrial equipment and wireless communication devices.

2)   The ISM interference level most likely would be too high to process out completely.

3)   Signal processing could reduce the sensitivity of the MSS receivers.

6.3   Increased Power of MSS Downlinks

The ITU radio regulations establish a PFD coordination trigger of -142 dBW/sq m/4 kHz. Generally the MSS systems using this band operate at or near this limit in order to maximize their capacity and avoid interference to other users in the band.

If the power per channel is increased in the MSS downlink to overcome the interfering power, the number of channels served must be decreased. This would reduce the overall system capacity.

Since the interference power is likely to be very high compared to the thermal noise, it is questionable whether the MSS satellite would be able to transmit sufficient power to overcome the interference noise and provide a usable signal-to-noise ratio to the MSS receivers. The result will be that the MSS capacity in populated areas will be substantially reduced.

6.4   Area Avoidance

A suggested solution could be the use of dual mode user terminals that would contain both a cellular radio and an MSS radio. The cellular radio could be used in populated areas that have cellular coverage and the satellite radio could be used in remote or unpopulated areas.

7 Conclusions

- **ISM Interference is likely to exceed greatly the thermal noise in populated areas.**

The data taken during the NTIA tests indicate that a significant ISM interference noise floor exists in populated areas that contain microwave ovens and other ISM emitters. Any user terminal in the Mobile Satellite Service operating in populated areas will experience varying high level interference noise that will greatly exceed the thermal noise.

- **ISM interference is likely to increase and be more diverse**

Although the present sources of ISM interference are likely to be microwave ovens, new uses in the industrial, lighting and wireless communication systems are being developed that will cause an increase in the general level of interference. Also, the types of interference will become more diverse as the different types of uses become more prevalent.

- **There are no adequate solutions to ISM interference**

Suppression of ISM emissions, signal processing or increased satellite downlink power are not likely to be among the potential solutions to the problem.

- **Area Avoidance may be the only potential solution**

Avoiding the use of the satellite system in virtually all populated areas may be the only method for resolving the ISM interference problem. Since most of the urban and suburban areas are covered with cellular communication systems, use of a dual mode user terminal, MSS and cellular, could help avoid many of the interference scenarios but would restrict the overall availability of MSS service.

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